Highlights

- **TWIN, 15 SPAN, CAST IN PLACE, SINGLE CELL, SEGMENTAL CONCRETE BOX GIRDER SUPERSTRUCTURE**
- **THE FOUR SPAN, NORTH CHANNEL PEDESTRIAN BRIDGE IS SUSPENDED BETWEEN SUPERSTRUCTURE GIRDERS**

SPANS

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ROBERT E. LEE'S STIRRUPS CARRY NORTH CHANNEL WALKWAY

Historic Richmond, Virginia is the State Capitol and, in another era, it was the Capitol of the Confederate States of America. The American Civil War had its heroes and villains with Abraham Lincoln foremost among the heroes and, somewhere among these heroes was a prominent Civil Engineer named Robert E. Lee who also served as General of the Army of Northern Virginia. General Lee spent many years in the saddle as a soldier but ended his career as a University President at what today is called Washington & Lee University. To honor a prominent native son a river crossing, built in the early 20's by the City of Richmond, was named the Robert E. Lee Bridge.

Before the Interstate (I-95) System, the main north-south roadway on the US east coast, extending from the tip of Key West, Florida to Maine, was known as US Route 1 which goes through Richmond. This long traveled route crosses the James River at a location where Belle Island separates the river into the north and south channels (Figure 1). After the new bridge was opened in 1987 the city agency known as Richmond Renaissance considered it to be a good idea to open the 54 acre island as a park, in the middle of the city. The thought then was to add an independent pedestrian bridge next to and below the onrushing traffic, high above the river,

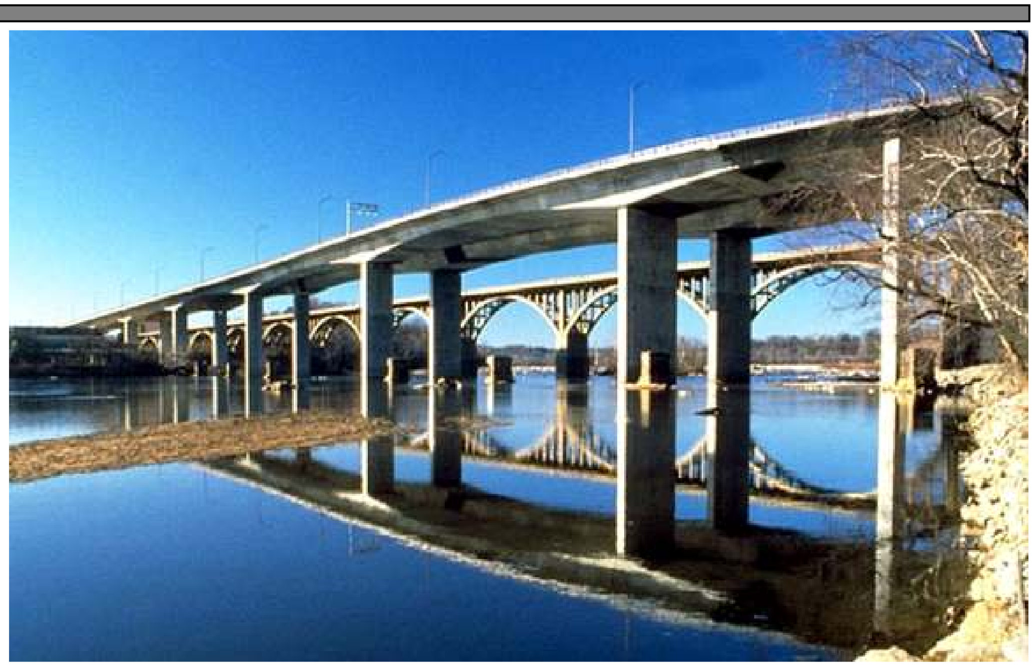

FIGURE 1: A 1987 view looking SW across the North Chanel of the James River Bridge, existing (foreground) and predecessor (back ground)

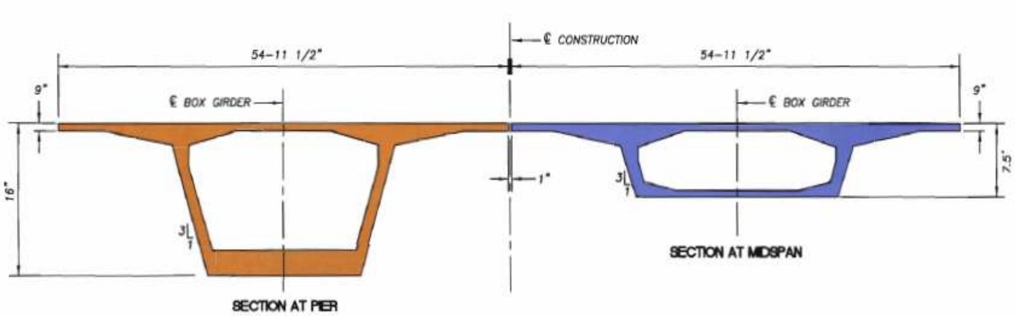

FIGURE 2: Cross section for typical, twin-girder, superstructure from which the 8' wide, walkway is suspended and centered.

FIGURE 3: View from the north bank of the James River of the Robert E. Lee bridge and the suspended walkway to Bell Island

to afford public access to this tranquil, green area.

The Roanoke based general engineering consultant, Heay, Seay, Mattern & Mattern (HSMM) was under contract in 1979 to study the replacement for the 50 year old Robert E. Lee Bridge in Richmond. They were led by their Business Development Director, Howard Noel, P.E., who introduced DRC Consultants Inc. to their company as a segmental concrete specialist. HSMM advanced their study with full consideration given to both steel and concrete solutions in order to evaluate both alternates and make a recommendation to the client as to which design was the least costly for bidding purposes.

However, during this period of time, the Federal Highway Administration (FHWA) began requiring that both designs go to bid despite the additional cost of producing two sets of bid documents by two different consultants. HSMM opted to do the concrete with DRC in this real market competition. The Virginia Department of Highways and Transportation (VDOHT), representing the interests of the owner, the City of Richmond, advertised alternate designs in steel and concrete for the bridge replacement, in 1984.

The low bid of $32,165,161 for the cast-in-place, segmental concrete, box girder, designed by HSMM-DRC Consultants Inc. was submitted by the General Contractors, McCarthy Bros. from St. Louis, Missouri. This 3755' long, 15 span twin structure (Figure 2), carries 3-lanes each way in a north-south direction with an out to out superstructure dimension of 110' and having a roadway typically 91' above the river. The spans range from a minimum of 122' to a maximum of 302'and with a typical length of 285'.

Further to the design contract the HSMM-DRC team was awarded the Construction Engineering & Inspection (CE&I) contract for the construction phase of the project. DRC's Philip Lang, P.E. and Teddy Theryo, P.E. were the CE&I field representatives working with McCarthy's Project Superintendent, Ralph Salamie, P. E.. Eight sets of form-travelers were utilized to simultaneously build each line of girders from the north to the south. The contractor would develop his casting curves to anticipate the desired geometry for the finished

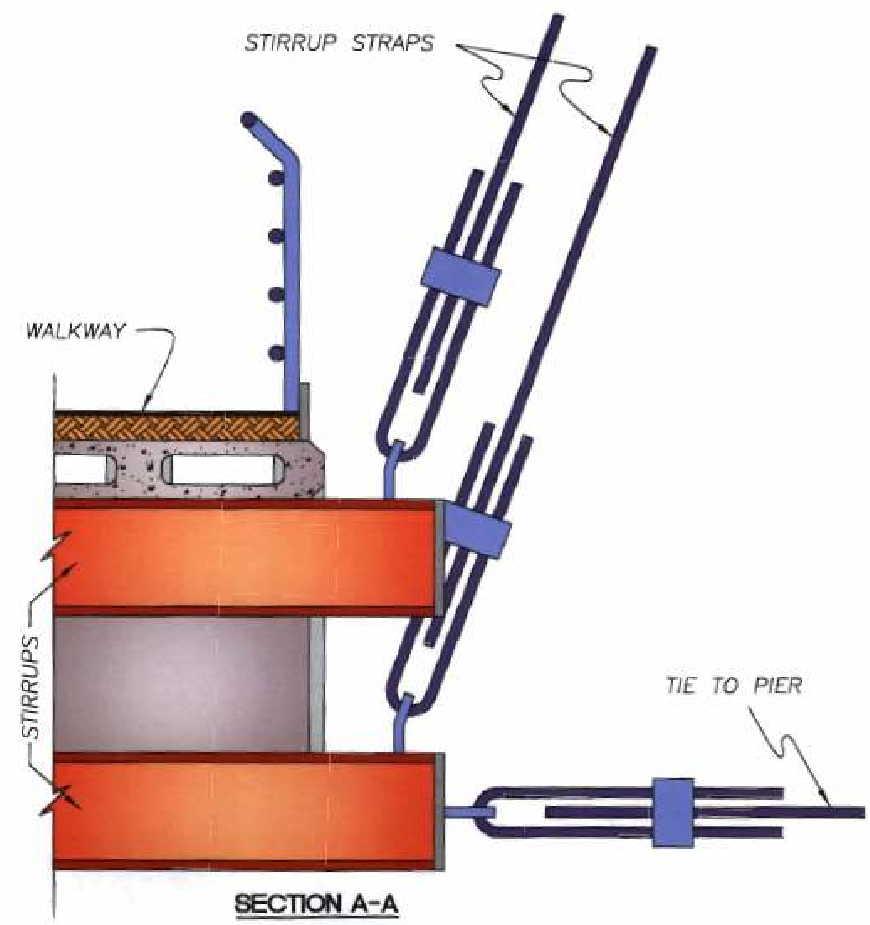

FIGURE 4: Turnbuckles connect stirrups to hangar straps and ties

FIGURE 5: Eight foot wide walkway rises and falls, suspended between 75' tall, cathedral like columns carrying visitors to 54 acre Bell Island

superstructure. The CE&I Consultant would review the predicted geometry and verify the resulting concrete configuration to see that the structure was in compliance with the contract documents.

With cast-in-place (CIP), balanced cantilever, segmental concrete construction one of the advantages is that the segments are double the size of pre-cast, balanced cantilever, segmental construction; however, these CIP segments are twice the concrete weight plus the included form traveler than their pre-cast counterparts. Therefore, when pouring one off-set segment the eccentric, unbalanced loads will induce larger, unwanted stresses into the preceding structural matrix than the smaller, lighter, pre-cast segments would.

To minimize the moments induced from the eccentric loading caused by the progressing, cantilevering, superstructure, and attached form travelers, steel brackets at the juncture of the pier and girder were installed anticipating the first three segments. For the anticipated, eccentric loading from segment number 4 to mid-span chin-stays were temporarily installed to reduce the induced moments from superstructure tipping.

DRC suggested to Richmond Renaissance that it would be cost effective to suspend the eight foot wide pedestrian bridge from the superstructure (Figure 2) rather than build on river piers, and they agreed. This engineering consultant provided a concept to suspend the pedestrian bridge from the four, 285', North Channel spans so that it would hang between the twin lines of piers (Figure 3). The Richmond Fine Arts Commission had originally established that the replacement bridge spans have a variable depth to emulate the open spandrel arch structure that it replaced.

Implementation of the concept of combining both structures confirmed that the natural location of the walkway was to hang it from the newly constructed, overhead girders and have it pass between the twin lines of attendant, cathedral-like piers. A level profile-grade-line would have been subscribing to the ordinary so; it was decided to have the four spans instead, leap-frog from pier to pier reflecting the variable, girder depths overhead (Figure 3).

The supporting cable orientation, in the longitudinal direction, has a radiating pattern with cables perpendicular to the arched deck profile. The view from a transverse section through the walkway (Figure 4) shows the cables leaning away from the deck edges and reaching up to their more widely spaced attachment locations at the girders above.

This hanging walkway concept was accepted, with certain conditions. The cost estimate was to include the condition for the use of a temporary causeway being a part of the bid documents for the pedestrian bridge. The abutments, at each end of the pedestrian bridge, are steel frames locked to the piers which slope down to grade at a gentle ADA prescribed slope. The suspended walkway deck is horizontally stabilized at the three intervening piers by horizontally tensioned steel brackets (Figure 4).

The static analysis of the support system revealed that the pedestrian bridge arches and their inclined hangars act integrally as an arch and suspension system. This dual capacity permits some flexibility for one-sided loading conditions (pedestrians all gathered on one handrail to view a passing boat) which are characteristic of cable structures. The design had to accommodate these actions and both tension and compression steel was provided in the pre-cast, walkway slabs. The abutments were a combination of both cantilevered and suspended steel beams.

This unique footbridge was bid and built by a young contractor who employed some innovative measures to construct the bridge. He developed a methodology to position all the hangars in their planned matrix and he built a launching platform that spanned from stirrup to stirrup which facilitated the installation of the pre-cast plank, walkway floors. All construction took place above the river so that no temporary causeway was required. The Belle Island Pedestrian Bridge was dedicated by the City of Richmond on April 30, 1991 (Figure 5).

The Contractor discovered a Guernsey cow that had been the only resident since the Civil War ended 142 years, previously. Then, Belle Island was used as a prisoner of war camp for captured Union Troops. The cow was apparently washed ashore during a spring flood and no one knows how long she had been languishing about on her island. Moreover, the north bank has the old Tredegar Ironworks that produced cannons and most of the ordinance for the Confederacy.

The uniqueness of the walkway and the unusual feeling of almost flying across the river adds a thrill for visitors to the island. The pedestrian bridge is becoming a destination attraction in itself, though still a distant second to the historic reasons tourists are drawn to the area . And, locals now have a green refuge, away from the din of a busy metropolitan area that they can retreat to. The pedestrian bridge, much like the General himself standing in his stirrups, is supported by the Robert E. Lee Bridge.

Guest Commentary

By: Tim Noles

Mathews Bridge Deck Replacement

Mathews Bridge located in Jacksonville, Florida spans the St. Johns River, bringing traffic along Arlington Expressway and Downtown. It was named after John E. Mathews, a Florida state legislator and Chief Justice of the 1955 Florida Supreme Court who helped gather funding for the bridge's construction. The cantilevered type through truss design was a common long span design utilized from the early 1900's through the 1950's. In order to minimize weight of the 810 ft main channel span, which is suspended from the flanking anchor spans, the original deck was constructed of a lightweight steel grating system commonly seen on movable bridges. Since the length of the grating system exceeded 800 ft the rideability of the span was treacherous, especially in rainy conditions.
After the original grating wore out, a new one was installed in 1997, causing drivers to complain that the replacement was slippery and more difficult to cross. That grating was replaced with a new grating, which also provoked controversy causing citizens to pressure the Jacksonville City Council to act. This resulted in reducing the speed limit and roughing up the grating.
With continued complaints about the rideability of the roadway, the FDOT decided to replace the new deck with a solid deck surface design. Hardesty & Hanover, LLP, RS&H Inc., and BPA Associates Inc. were selected by the FDOT to replace the grating with a solid deck system. Design challenges included maintaining the load carrying capacity of the bridge structural components (most importantly the truss members and floorbeams), maintaining traffic, and minimizing construction time.
The following issues were considered key to the success of the project:

- Provide a new solid deck system that meets the following requirements:

1. Minimizes dead load to the span so that truss component strengthening is minimized.
2..Durable surface requiring minimal maintenance.
3. Improved rideability and skid resistance.
4. Provides corrosion protection to the steel paint system.

- The rehabilitated span should meet current AASHTO - LFRD criteria.
- Provide a Maintenance of Traffic (MOT) plan agreed to by local community groups. (90 day closure of two lanes of traffic)

Deck Type	Weight (psf)	Truss Members Strengthened	M.O.T (Days)	Cost ($MM)
6.5", LW, composite concrete	37	68	270	19.1
5" - 4 way, epoxy fill, steel grating	12	28	90	17.9
3 ¼", CIP, concrete deck integral w/steel grating (Exodermic)	24.6	36	90	18.6

H&H's experience in designing lightweight deck systems for movable bridges provided the knowledge necessary to design an efficient system. H&H performed an evaluation of the following alternatives which have all also been utilized for movable bridge decks.
Although the material costs are similar, it was determined that the Exodermic deck system provided the most cost effective system due to the lower number of truss members requiring strengthening, and the added benefit of composite design which strengthens the existing floorbeams. In addition, the exodermic system had the advantage over the epoxy filled grating since the broadcasted aggregate wearing surface requires periodic maintenance to preserve the required skid resistance.
The amount of time required to remove and replace the deck systems fit within the 90 day schedule. Contractors were consulted during the design phase to ensure the aggressive schedule was possible.
An Exodermic deck system utilizes the benefits of a grating system and a concrete deck. The grating system is utilized as an external steel reinforcement of the concrete deck which is placed over a steel grating system. This system provids longer spans than filled grating and therefore requires less stringer beams. Less stringers spanning between floorbeams provides a more efficient lightweight deck, especially with the use of lightweight concrete (LW) commonly used on bascule spans (115 pcf).
The truss required strengthening only of the top chord members at the center span locations to provide the necessary strength to support the heavier deck. The transverse floor beams, now composite with the deck with the addition of Nelson Studs were strengthened and now rate for an HL-93, and Florida Legal Truck Load configuration under LRFD - AASHTO criteria.
The project came under the $18.6 million budget at $12.9 million performed by PCL Constructors, and began January, 2007. PCL removed and replaced the deck system within the required 90 day period and received a $500,000 incentive bonus in doing so.
This project satisfied the FDOT requirements and ensured safety of the traveling public while receiving nothing but accolades by all. The project recently won an ACI Award for Bridge Rehabilitation.

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